Attorney Docket Number:
2594 EFC-4

UNITED STATES PATENT APPLICATION

of

GUNNAR VAN DER STEUR

for:

APPARATUS AND METHOD FOR ELECTROSTATIC SPRAYING OF CONDUCTIVE COATING MATERIALS

APPARATUS AND METHOD FOR ELECTROSTATIC SPRAYING OF CONDUCTIVE COATING MATERIALS

FIELD OF THE INVENTION

The invention relates to the electrostatic spray coating of articles generally, and is particularly suited for the spray painting of automotive vehicles with water based paint.

BACKGROUND OF THE INVENTION

In the electrostatic application of paint in the automotive finishing industry, paint may be delivered to a robotically maneuverable atomizer applicator from a plurality of sources, each source providing a different color paint. During application, a high voltage is imposed on the paint, which imparts positive charges on the atomized paint droplets, which are then uniformly attracted to grounded articles being coated, all in known assembly-line fashion. Water based paint is, generally, electrically conductive. Conductivity of the paint composition can create critical safety concerns and hazards in electrostatic operations, wherein the applicator itself must be maintained at a high voltage.

Concomitantly, recently enacted environmental constraints are exerting pressure on the automotive industry to reduce the amount of volatile organic compounds (VOCs) being released into the environment, the majority of which is produced by paint operations. To reduce VOC emissions, painting facilities have gradually been converting from solvent paint carrier systems to water based systems. Water based paint, although much lower in VOC content, creates another set of problems resulting from the electrostatic charges placed on the paint as it leaves the spray atomizer. The charge can travel back down through the electrically conductive paint, acting as a circuit, to ground, thereby presenting a safety concern. The solution is to completely isolate the charged conductive paint being atomized from ground during the painting process.

Several attempts have been undertaken to isolate the high voltage required for electrostatic painting from ground when using conductive, water based paint. One such system to provide galvanic isolation is disclosed in U.S. Patent 4,785,760. This patent describes an electrostatic system for spraying conductive paint wherein a quantity of paint required to paint an object such as a vehicle is stored in a storage tank carried by a multi-axis robot. The spray applicator may be of the

rotational, bell cup variety or the pneumatic or hydrostatic spray gun type. The sprayer, carried by the robot, is supplied during painting from a storage tank also mounted on the robot arm and connected to the sprayer. The high voltage generator itself is controllable, that is, its output voltage may be reduced to zero at any time and then re-established virtually instantaneously using conventional controls. See, e.g., the '760 patent at col. 5, line 16 et seq. The high voltage is reduced to zero before a color change cycle is initiated, the storage tank is filled at a local dispensing port, and the voltage is re-established after filling as spraying begins again, resulting in isolation of the high voltage during spraying from the various distribution circuits that are all electrically grounded, because there is no conductive paint conduit connecting them during the spraying operation. ('760, col. 6, lines 57-65).

U.S. Patent 5,310,120 discusses the '760 patent and discloses an alternative storage tank for an electrically conductive liquid coating product. This patent discloses a procedure wherein the coating product, at a high voltage, is carried within a storage tank defined by a substantially cylindrical cavity formed in an insulative

material body inside of which is a piston forming a mobile wall separating a coating product chamber from an actuation chamber filled with an electrically insulative actuation fluid. During spraying, because the tank is separated and isolated from the grounded robot carrying it, the electrostatic charge placed on the paint within the storage tank will not track back to ground.

In one further known operation for providing such isolation, an intermediate storage tank is filled with sufficient paint required for one application. Each color change requires that the intermediate tank and the conduits leading to it be cleaned, for example as disclosed in French patent No. 2,572,662. Galvanic isolation is re-established after filling the intermediate tank by draining and drying a sufficient length of conduit upstream of the intermediate storage tank and then commencing painting. This method, however, is said to require a "prohibitive length of time" on each color, and therefore to be "not practical". See, e.g., U.S. Patent 4,785,760, at col. 3, line 25 et seq.

As a point of reference, the '760 patent suggests providing the necessary galvanic isolation by a method involving robotically picking up one small storage tank **22**, spraying its contents, and then "hanging it up" locally and getting another one. See, e.g., '760 at col. 7, line 62 et seq.

While such apparatus and procedures may isolate the charged spray paint, they are generally inefficient. Time is of the essence on the paint finish line, an entire vehicle being painted typically in 2-3 minutes. Travel time in these operations in manipulating storage tanks robotically around a paint room is costly. The more time that is spent in emptying, cleaning and color changing, the more costly is the process. It is therefore beneficial to have a system that does not require transporting storage tanks with affixed applicators by means of robot arms to and from paint distributing docking systems, and which can be directly connected to paint supply tanks, all while maintaining complete voltage isolation from ground of the paint being sprayed.

The present invention provides such a system.

SUMMARY OF THE INVENTION

Apparatus and a method are provided for isolating an electrostatic sprayer from an electrically grounded coating product distribution circuit connected thereto. The apparatus includes an electrostatic sprayer carried by a maneuverable robot arm, the sprayer capable of spraying an electrically conductive coating product such as water-based paint onto a workpiece passing in adjacent proximity thereby, on command. The coating product is supplied from a source of supply through at least one distribution circuit connected to the sprayer. The apparatus includes therein, carried by the robot arm, an electrically insulative storage tank for the coating product in valved fluid communication with the sprayer. The insulated storage tank is connected to and positioned downstream in the distribution circuit from a length of electrically insulative supply conduit. The length of supply conduit is connected to the distribution circuit and is also carried by the robot arm. The length of supply conduit includes a cleaning mechanism for cleaning a portion, including all, of the length of supply conduit, in situ, after filling of the storage tank with coating product and before spraying. In this way, substantially all of the conductive coating product is

removed from the portion of supply conduit, thereby completely isolating the sprayer electrically from the distribution circuit. The storage tank and supply conduit are preferably formed within a unitary housing made of a non-conductive plastic such as polyacetal resin.

In a preferred embodiment, containment and storage of the coating product prior to spraying are effected within a deformable membrane housed within the storage tank. Spraying is effected by a metering pump positioned downstream of the storage tank and upstream from the sprayer, and preferably the pump is a gear pump.

The membrane can be made of an elastomer, and is preferably a fluoroelastomer such as a fluorinated ethylene propylene (FEP) elastomer or a perfluoroalkyl (PFA) elastomer.

In alternate embodiments, containment and storage of the coating product can be effected within the chamber of a piston-and-cylinder assembly housed within the storage tank prior to spraying or within a balloon-like chamber housed within the storage tank prior to spraying.

Preferably the supply conduit is tubular and the mechanism for cleaning the supply conduit includes a plunger positioned within the conduit and adapted to reciprocally and repeatedly traverse the length of the

conduit. The plunger is preferably made of a fluoroelastomer such as FEP.

The apparatus includes driving means for driving the plunger reciprocally back-and-forth through the length of said conduit on command, and the driving means may be air under pressure controlled by valving. In this embodiment, the apparatus has a valve-controlled source of compressed air connected thereto.

To clean the system, the apparatus includes a valve-controlled source of solvent connected within the distribution circuit, and a preferred solvent is deionized water. The apparatus includes a high voltage generator, preferably carried within the apparatus of the invention, the generator being supplied with low voltage via an isolated connector from an external voltage source.

The apparatus may be connected to a plurality of coating product distribution circuits, these circuits optionally distributing coatings of different colors as desired.

A facility for coating a plurality of workpieces simultaneously is contemplated, the installation including a plurality of the apparatus as aforesaid connected to a plurality of coating product distribution circuits. The apparatus is especially suited for coating automotive vehicles.

A process according to the invention is also provided for electrostatically spraying an electrically conductive coating onto a work-piece. The process includes spraying a conductive coating such as water-based paint onto a workpiece passing in adjacent proximity thereto using an electrostatic sprayer carried by a maneuverable robot arm. The batch-operation spraying begins after first supplying the coating to the sprayer system from a source of supply through at least one grounded distribution circuit connected to the sprayer, wherein the distribution circuit includes therein, carried by the robot arm, an electrically insulative storage tank for the coating composition in valved fluid communication with the sprayer and being connected to and positioned downstream from a length of electrically insulative supply conduit. The length of supply conduit is also carried by the robot arm. The process includes cleaning a portion, including all, of the length of the supply conduit, in situ, after filling of the storage tank with coating product and before spraying, thereby removing substantially all of the conductive coating product from the portion of supply conduit within the distribution circuit. This results in isolation of the sprayer electrically from the distribution circuit before actual spraying.

This process of cleaning the supply conduit, using a plunger fitted therein adapted to reciprocally traverse the length of the conduit, effectively wipes it clean of coating product and galvanically isolates the sprayer from the distribution circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is an external isometric view of the electrostatic spray coating apparatus of the invention attached to the end of a multi-axially maneuverable robotic arm, showing its housing and all fluid and electrical supply (and discharge) lines;

Fig. 2 is a side elevation of the paint applicator and storage chamber of the invention, showing the various supply, return and discharge lines and electric conduit;

Fig. 3 is a cross-sectional view of the paint applicator and storage chamber of one embodiment of the apparatus of the invention, illustrating certain internal components thereof;

Figs. 4-7 illustrate, schematically, fluid conduits and valving employed in the preferred apparatus of the invention;

Figs. 8-12 illustrate schematically a sequence of steps to be encountered in the filling and electrically isolating from ground the storage chamber and spray applicator, and the spray operation, according to the invention;

Figs. 13-16 illustrate schematically a sequence of steps encountered in the cleaning and preparing of the storage chamber and spray applicator according to the invention for a new spray cycle;

Fig. 17 is a schematic illustration of a piston-and cylinder type of storage chamber in an alternate embodiment of the invention; and

Fig. 18 is a schematic illustration of a balloon-type of storage chamber in a further alternate embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS WITH REFERENCE TO THE DRAWINGS

Electrostatic spray applicators, as discussed hereinabove, are widely used for spray coating of substrates such as automotive vehicles. Sprayers are typically mounted on and maneuvered by programmable robots in automated production lines. Hydrostatic or pneumatic spray gun applicators or rotary bell cup applicators are typically used to uniformly paint automobiles carried by conveyor to and through a paint booth or area. The time required to actually paint a vehicle typically can range from a few to several minutes. Successive vehicles often must be painted different colors, requiring multiple changing of paint colors at a particular painting station as the production progresses.

Paint supply tanks are generally located remotely from a local painting station, and paint is supplied via distribution lines from these remote storage tanks. In addition, in electrostatic spraying operations using water based, i.e. electrically conductive, paint compositions, which operations involve a high voltage source in implementing uniform coatings, it is imperative that the highly charged spray applicator be galvanically isolated from the grounded paint supply.

In stark contrast to prior techniques for providing such isolation, the present invention provides apparatus and a method for filling, cleaning and electrically isolating a paint storage tank and its associated applicator, in situ, all mounted on the end of a robot controlled arm, and all while maintaining continuous connections to a plurality of paint distribution sources, as needed. According to the invention, there are no multiple connect and disconnect operations of a plurality of storage tanks, or passing of same by robotic arms around a paint room operation, as occurs with certain prior art procedures.

The invention, concisely, provides apparatus and a method for electrically isolating, in situ, a length of the paint feed line leading to a storage compartment for paint to be sprayed onto a workpiece, after filling of the compartment, wherein the compartment and its associated spray applicator are carried by, and maneuvered by, a robot arm.

A detailed description of the invention and preferred embodiments is best provided with reference to the accompanying drawings wherein Fig. 1 is a schematic isometric view of electrostatic paint spraying apparatus according to the invention having a rotary bell cup applicator **20** affixed to the end of a maneuverable robot

arm **30** by quick-disconnect nut **16**, the applicator applying atomized, electrically charged paint **25** to a workpiece **48**. The bell cup spray applicator **20** is affixed to a manifold housing **26** through which is fed the paint and shaping air supplied from inlet paint distribution means **50** and air supply **60**. A turbine which drives the rotational bell cup, described below, is housed within housing **22** and is air driven, with air being supplied through air inlet **58**. The atomized paint **25** (and shaping air) is discharged from the applicator **20** in a lateral direction, at which point the droplets acquire a charge. Shaping air supplied through hose **60** is routed through the manifold housing **26** and the housing **22** and exits the assembly to help direct the paint **25** over the workpiece **48**. The charged paint is then attracted to and deposited on grounded article **48**, all as depicted in Fig. 1. The electrostatic field is generated by the electrical source, **62**, and the internal voltage potential is maintained at a high voltage, e.g., 80 KV, above ground potential, placing a charge on the particles being emitted from the spray applicator **20** and being deposited as shown onto the grounded substrate **48** to be coated.

Fig. 1 illustrates, schematically, one embodiment of a paint storage chamber **10** carried by the robot arm **30** and affixed thereto by quick-disconnect nut **16**, all discussed in detail below. The spray applicator **20** affixed to storage means **10** and connected, as shown, by nut **16** to the robot arm connector **18**, is manipulated in three-dimensional space by pivotable housing **32**, rotatable as shown by the double headed arrow, about pivot **34**, affixed to base plate **36** by extension joint **38**, which is rotatable by means of rotating joint **40**, indicated by the arrow. Coupling **44** connects this joint to the end **46** of the robot arm, and the arm segment **46** is axially moveable, also as indicated by the arrow shown. For completeness, the bundle of air/paint/solvent supply conduits is shown, including therein the low voltage supply conduit **62**, all described more fully below, as well as extension joints **38**, **42** and applicator manifold access plate **28**.

Fig. 2 is a side elevation of the storage means **10** and applicator assembly **20**, and peripherals, of the embodiment depicted in Fig. 1. Therein, the bundle of supply conduits, including paint supply **50**, solvent **52** and air **53** supplies for cleaning operations, air **54** for triggering the various pneumatic valves discussed below,

air **56** for adjustment of a storage bladder, air **57** for driving the cleaning plunger, air **58** to power the turbine, air **60** for shaping the paint spray, and the voltage supply conduit **62**, are all routed through the robot arm connector **18** (in phantom) and into the storage chamber housing **14**. Affixed to the downstream side of the storage chamber assembly **10**, by quick disconnect nut **12**, is the applicator assembly **20**. This assembly includes the manifold housing **26** and bell cup spray applicator assembly **20** affixed thereto by connecting nut **24**. The outer shroud **22** and the rotating bell cup **23** of the applicator assembly **20** are visible in this figure as are the removable access plate **28** and the waste discharge tube **84**, described more fully below with reference to Fig. 3.

One embodiment of the storage apparatus **10** and rotating bell cup spray applicator assembly **20** of the invention is shown in greater detail in the cross-sectional view of Fig. 3. The applicator assembly **20** includes therein the bell cup body **23**, outer shroud **22**, inner shroud **21**, turbine **76**, turbine quick disconnect nut **22'** and rotatable deflector **69**. The manifold housing **26** has electrostatically insulative internal passages, not shown, through which the coating composition is transported from the stationary, non-rotating coaxial

supply channel **50**, into the central cavity **86**, into stationery paint injection tube **78**, and into and out through the annular discharging outlet extending around the outer periphery of deflector **69**.

Controlled low voltage (0 to 21 volts, d.c.) is supplied from cable **62**. The internal cascade unit **66** steps the voltage up to as much as 100,000 volts. The high voltage is then transmitted through the manifold **26** to the turbine (air bearing motor) **76**. The charge is placed on the bell cup assembly by a series of conductive fiber brushes (not shown) which touch the rotating shaft **75** within the turbine **76**.

The bell cup body **23** is conventionally affixed to an electrically conductive turbine shaft **75** within the turbine assembly **76**. The rotating shaft **75** of the compressed air turbine **76** drives the rotating bell cup assembly, including the body **23** and deflector **69**, which expels the atomized paint from the applicator assembly.

Upstream from the applicator **20** is the storage chamber **10**, which includes its auxiliary fluid circuitry, all according to the invention. The chamber assembly **10** has affixed to it the applicator assembly **20** by means of quick disconnect nut **12**. The chamber **10** is affixed to the robot side base plate **30** by means of quick disconnect

nut **16**. The storage chamber apparatus **10** in the embodiment shown in Fig. 3 includes outer insulative housing **14** having convex cavity **72** therein. Cavity **72** extends annularly and circumferentially, as shown, around cylindrical sleeve **74** which encircles the central support housing **15** of the storage chamber **10**. Sealingly affixed to both ends of sleeve **74** is a bladder **70**. A valved (V2) channel **82** formed in sleeve **74** provides fluid communication between paint supply inlet **50**, through the paint fill line **80**, and thence, valved, into the gap between the bladder **70** and the sleeve **74** when the valve V2 is opened appropriately, resulting in the filling of and storage of paint within the bladder **70** contained by the walls of the convex cavity **72**.

The storage tank housing **14**, the sleeve **74** and the central support housing **15** are all made of an electrically insulative plastic material, preferably a polyacetal resin sold under the trademark DELRIN®. The bladder **70** is preferably of an elastomer, preferably a synthetic fluoroelastomer. Especially preferred is a membrane of fluorinated ethylene propylene (FEP) elastomer.

Formed within the central housing **15** is the paint fill line **80** preferably extending from an upstream valved (V1) inlet **50** through the central housing **15** to a valved (V2) outlet line **82**. Upon command, paint enters through the paint fill line **80** from supply conduit **50**, proceeds through line **82** to fill the bladder **70**, at which point the supply is shut off.

From this stage of operation on, with the filled bladder **70** intact, the paint fill line **80** may be cleaned of all conductive paint, and dried, all as described below, thereby electrically isolating the stored paint in the bladder **70** and the applicator assembly **20** from the rest of apparatus. After such cleaning, and with the opening of valve V3, the painting operation proceeds, preferably by means of a metered gear pump (not seen) drawing paint from the storage bladder **70** and expelling it outwardly through the rotary bell cup applicator **20**, all in complete electrical isolation from ground.

Before describing in detail the sequence of operative steps of filling the storage bladder **70**, cleaning the fill line **80** to galvanically isolate the system, painting, flushing and refilling before a second painting operation, reference is re-directed to Fig. 3 to illustrate a preferred mechanism for cleaning and drying

the fill conduit **80** after the bladder **70** is filled. Positioned relatively snugly, and fluid sealingly, within fill tube **80** is plunger **64**, preferably also made of a fluoroelastomer as discussed. The plunger **64** is reciprocally driveable, back and forth through fill tube **80**, its direction of traverse being controlled by air and appropriate valving (V4 and V5, V5 not seen in this figure) positioned at either end of fill tube **80**. Thus, with V4 (see Fig. 4 also) open to air line **53** and V2 open to discharge line **84** only, air drives the plunger **64** from the leftmost location of tube **80** in Fig. 3 to the rightmost location. In so doing, the plunger **64** acts as a squeegee and forces residual paint out of the fill tube **80** and to discharge through discharge tube **84** to waste. Reversing this operation returns the plunger **64** to its leftmost location. A controlled series of such operations is clearly contemplated and described in detail hereinbelow.

In Fig. 3, the electrical cascade **66** and electrical conduits **68**, housed within the central support housing **15**, and the low voltage supply conduit **62** are all shown for completeness. Omitted from Fig. 3, and not seen in this view, is the pathway of the paint line **86** from its entry into applicator **20** (shown) and backwardly to and through its pumping means and further upstream into the

bladder **70** storage volume (shown schematically in Figs. 4 and 5). One skilled in the art will understand this channeling with reference to Figs. 4-16 hereinbelow.

The schematic diagrams of Figs. 4-7 and Figs. 8-16 all serve to illustrate the various key components of the invention and their respective functions. In Figs. 4-7, the diagrams show the fill tube **80** and its adjacent peripherals and only the lower diagrammatic portion of the storage bladder **70**, it being understood that the cavity **72** defined by the outer housing **14** and the inner sleeve **74**, with bladder **70** affixed thereto at either end, extends circumferentially around the central support housing **15**. These figures are to be viewed together with Fig. 3.

At the beginning of a paint cycle, with the entire system clean, with reference to Fig. 4, the plunger **64** is positioned at its leftmost rest position. Valves V4 and V2 are closed as shown, as are valves V1, V3 and V5 (air line). Valve V6 is closed, and this represents the sealed rest position for a clean system.

When painting is desired, referring to Fig. 5, valve V6 is opened to atmosphere and valve V2 is opened as shown to allow passage from the fill tube **80** into the bladder storage volume. Opening valve V1 as shown then allows paint to enter fill line **80** from paint line **50**,

proceed through the tube **80** through conduit **82** and into the space between the sleeve **74** (Fig. 3) and the bladder **70**, filling it as shown in Fig. 5. The valving may be controlled by pneumatic signals by known techniques. As paint enters, the bladder **70** expands until it is filled to capacity, which is determined by flow rate and fill time, at which point valves V1, V2 and V6 are closed.

With reference to Figs. 5, 5A and 6, in order to safely apply paint to the workpiece electrostatically, at least a portion of the conductive paint path from the grounded paint distribution line **50** to the storage bladder **70** can be interrupted, such as by cleaning all residual paint out of the fill line **80** and drying this line, prior to spray painting. To accomplish this, referring to Fig. 5A, solvent (water) is injected into the system by opening V1 to solvent supply line **52** to allow solvent to pass into and through tube **80**, then to and through discharge line **84** (valve V2 being opened), to flush out tube **80** and clean it. Valve V1 is closed and then, as shown in Fig. 6, valve V4 may be opened to air line **53**, driving the plunger **64** to its rightmost position, cleaning the walls of tube **80** by a squeegee action and forcing all excess solvent and residual paint out to waste through line **84**. To return the plunger **64** to its starting position, a pneumatic signal triggers

valve V5 to open to air line **57** and V2 is closed, while valve V4 is opened to exhaust **51**, thus driving the plunger **64** back to its start position, as shown in Fig. 7. This sequence of flushing with solvent and returning plunger **64** to its start position may be repeated as necessary. Air is finally purged through the system to dry it, by opening V4 to air line **53** and V2 to discharge **84** and thereby remove any conductive pathway between paint line **50** and the paint within the storage bladder **70**. Paint is then applied to the workpiece through paint line **86** with V3 open, V6 open to atmosphere, and all other valves closed.

It will be appreciated that alternative valving schemes may be employed to provide the fill-flush-dry operation according to the invention. The above is one example of such sequence.

Figs. 8-16 illustrate, in somewhat more detail, nonetheless schematically, the various steps in the process according to the invention. Fig. 8 illustrates an initial filling step. Therein, V1 is open to paint line **50**, V6 is open to atmosphere, and V2 is set as in Fig. 5 to connect tube **80** with the bladder fill opening **82**. Valves V3, V4 and V5 are closed. Paint, indicated by the solid arrow and the shading, enters from distribution line **50** and begins to fill bladder **70**.

Fig. 9 shows the filled bladder **70** and filled tube **80**, at which point V1, V2 and V6 are closed.

Fig. 10 illustrates the opening of valve V1 to line **52** to introduce solvent (water), indicated by the open (non-shaded) arrows into the fill line **80**, thereby flushing tube **80** with water and cleaning it of residual paint. In this figure, valves V3, V5 and V6 are closed, and V2 is adjusted to send the flushing components and residual paint to waste through tube **84**. See Fig. 5A.

By successively and alternatively opening and closing V4 and V5 to air, with V2 opened to waste and V4 opened to exhaust, as needed, and V1, V3 and V6 closed, all as illustrated in Fig. 11, the plunger **64** may be caused to reciprocally traverse the tube **80** as indicated by the arrows, driven therethrough by air. The leftmost and rightmost positions of plunger **64** in this operation are shown in phantom. Flushing may be repeated as necessary, all to completely flush, clean and dry tube **80**.

Painting begins at Fig. 12. Therein, valves V1, V2, V4 and V5 are closed. V3 is open, as is V6 (to atmosphere). Voltage is applied and paint **25** is drawn from the bladder **70** by a metering pump and is atomized and sprayed by means of rotary bell cup applicator **20**.

Fig. 13 illustrates the completion of the paint cycle and the depletion of paint within bladder **70**. At this point, the system can be flushed with solvent as shown in Fig. 14, leaving V3 open, opening V2 to waste, and introducing solvent/water into the system indicated by open (non-shaded) arrows through supply line **52**. Also, opening V2 as shown in Fig. 5 will permit the solvent to flush out the bladder. As shown in Fig. 15, closing V3 and opening V2 to connect the bladder interior to both tube **80** and discharge **84** and opening V6 to allow pressurized air, indicated by the smaller open arrows as shown, to compress the bladder **70** externally, would also aid in flushing the bladder. As illustrated by the several dashed lines **70** in Fig. 16, this operation may be repeated, causing the bladder to vibrate radially and rapidly, to help ensure that the bladder is completely cleaned of residual paint. The plunger **64** may be reciprocally driven back and forth through tube **80**, as needed, by opening and closing air valves V4 and V5, to wipe tube **80** free of residual liquid, as illustrated in Fig. 16.

After the storage bladder is completely flushed with solvent, air may be introduced into the system to dry the entire system, including the bladder. The paint fill cycle may then be repeated, with reference back to Fig. 8.

Fig. 17 is a simplified schematic diagram showing a possible configuration for piston-and-cylinder storage means **70′**, **72′** instead of a bladder, wherein like numbers designate like components in all figures.

Fig. 18 is a simplified schematic diagram showing a possible configuration for a balloon storage means **70′′** instead of a bladder, wherein an empty balloon **70′′** is shown in phantom and the filled balloon **70′′** is shown filling the chamber **72′′**, in a procedure similar to that employed with bladder **70**.

While the invention has been disclosed herein in connection with certain embodiments and detailed descriptions, it will be clear to one skilled in the art that modifications or variations of such details can be made without deviating from the gist of this invention, and such modifications or variations are considered to be within the scope of the claims hereinbelow.